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MINISTRY OF
HOUSING AND LOCAL GOVERNMENT

Metric Units with reference to water, sewage and related subjects

Report of Working Party

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Members of the working party

W. H. Norris, Esq., B.Sc., M.I.C.E., M.I.Mun.E. (Chairman)	Ministry of Housing and Local Government
A. Bleasdale, Esq., B.A., B.Sc.	Meteorological Office
A. Gérard Boulton, Esq., M.A., M.I.C.E., M.I.W.E.	Water Resources Board
Dr. A. L. Downing, D.Sc., M.A., B.Sc., A.M.I.Chem.E., F.I.Biol., F.Inst.W.P.C.	Water Pollution Research Laboratory
G. W. Froggatt, Esq., B.Eng., A.M.I.C.E., M.I.Mun.E.	Institution of Municipal Engineers
J. M. Haseldine, Esq., M.A., M.I.C.E., A.M.I.Mech.E.	Institution of Civil Engineers
W. S. Holden, Esq., B.Sc., F.R.I.C.	Society for Water Treatment and Examination
N. Medrington, Esq., A.M.I.C.E., M.I.W.E.	Association of River Authorities
K. C. Noble, Esq., B.Sc., A.M.I.C.E., A.M.I.W.E.	Ministry of Agriculture, Fisheries and Food
E. Field Reid, Esq., M.A., M.I.C.E., M.I.W.E.	Confederation of British Industry
J. L. Robinson, Esq.	Water Research Association
A. E. Round, Esq., B.Sc., M.I.C.E., M.I.W.E.	British Waterworks Association
H. H. Stanbridge, Esq., F.Inst.W.P.C., F.I.P.H.E.	Institute of Water Pollution Control
A. C. Twort, Esq., B.Sc., M.I.C.E., M.I.W.E.	Institution of Water Engineers
Col. J. S. Vickers, B.Sc. (Eng.), M.I.E.E.	British Standards Institution
H. L. Warburton, Esq.	Ministry of Housing and Local Government
D. A. Edmonds, Esq. (Secretary)	Ministry of Housing and Local Government

The working party on metrication with reference to water, sewage and related subjects was formed in January 1967 at the instigation of the Ministry of Housing and Local Government, the Ministry of Technology and the Water Resources Board. The working party was asked to advise on the selection of metric units in view of the forthcoming change to the metric system in the United Kingdom.

The members of the working party, which has met on five occasions, were nominated by the department or organisation named.

Introduction

1. At our first meeting we accepted the advice of the British Standards Institution that there should be an immediate change to the "Système International d'Unités" (SI) and that the "conventional" metric system of units should not be adopted as a halfway stage. The SI is a rationalised selection of units of the metric system which individually are not new. The main virtue of SI is that it is a system built up from no more than six basic units.

The six basic SI units are:

Quantity	*Name of unit*	*Unit symbol*
length	metre	m
mass	kilogramme	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	degree Kelvin	°K
luminous intensity	candela	cd

The use of SI units is explained in the B.S.I. publication PD 5686, (April 1967).

2. At the international meeting in Helsingør, June 1966, the attitude of the British delegation was "to be as consistent as possible in the selection of multiples and sub-multiples, taking into account established practice in certain fields". We have tried to follow this principle wherever possible in making our recommendations. In some cases where "international conformity" exists there are recommended deviations from SI.

3. Where units are applicable to manufactured articles we have recognised that the units we recommend should correspond with those adopted by the manufacturers. Manufacturers should be able to work in the same units whether for home markets or for export. The B.S.I. has stressed that the full advantages of the use of SI will not be gained by simply converting existing units to metric equivalents. New designs will eventually be prepared incorporating metric sizes and metric components, and taking into account international standards and practice in countries using the metric system. In this context we have been in some difficulty in not always knowing the trend of opinion in other countries which are adopting SI. (Already twenty-two nations, including most of the major industrial nations, have declared their intention of introducing legislation making SI the only legally acceptable units; of these, eleven have already introduced such legislation).

4. In the selection of units we have had regard to the orders of magnitude likely to arise in the field under review. Large or small numbers can be avoided by the use of the prefixes listed in Appendix 2. It should be noted that when a multiple of a basic unit is raised to a power, the power applies to the whole multiple and not to the basic unit alone.

Thus: $1\ \mathrm{km}^3 = 1\ (\mathrm{km})^3 = 10^9\ \mathrm{m}^3$ and not $1\,000\ \mathrm{m}^3$.

5. We have realised that the change to the new system provides an opportunity for the rationalisation of certain units and for the removal of inconsistencies which we believe exist in some units now in common use. We have, however, recognised that the difficulties involved in the change to the metric units could be increased by too drastic a change from current conceptions of the manner of presenting information. The difficulty in reconciling these points has been greatest in determining the extent to which cancellation of units should be recommended. For example, units like $\mathrm{m}^3/\mathrm{m}^3$ or $\mathrm{m}^3/\mathrm{m}^2$ can be simplified by cancellation. This could result in a changed concept of the information presented and, therefore, we recommend that where cancellation of units is likely to cause misunderstanding it should be avoided.

6. We are unanimous in recommending that the units set out in this report should be adopted in the field of water, sewage and all related subjects. The units we have listed are those which occur most frequently but the list is not intended to be exhaustive. The units we suggest are considered to be those most suitable for general use; other metric units may be used in special circumstances which render their use more appropriate.

7. It should be noted that a change of units will necessitate a change of constants in a number of commonly-used formulae.

Recommended Units

Description	Unit	Symbol	Comments
length	metre	m	*basic SI unit*
	kilometre	km	
	millimetre	mm	
area	square metre	m^2	
	square kilometre	km^2	
	square millimetre	mm^2	
	hectare	ha	the hectare (10 000 m^2) is a recognised multiple unit and will remain in international use.
volume	cubic metre	m^3	
	litre	l	the litre is now recognised as the special name for the cubic decimetre or 0·001 m^3.
mass	kilogramme	kg	*basic SI unit*
	gramme	g	
	milligramme	mg	
	tonne	t	1 tonne = 1 000 kg = 0·984 207 U.K. tons.
time	second	s	*basic SI unit*
	day	d	neither the day nor the year is an SI unit but both are important and natural units in this field and should be retained, in line with international practice. To preserve the coherence of the system the minute or hour should not be used except in special circumstances where the choice will depend on the discretion and convenience of the user. For instance, retention period in tanks is conveniently expressed in hours or minutes.
	year	a	
force	newton	N	the newton is that force which produces an acceleration of 1 m/s^2 in a mass of 1 kg
velocity			
(i) *linear*	metre per second	m/s	
	millimetre per second	mm/s	

RECOMMENDED UNITS (Contd.)

Description	Unit	Symbol	Comments
velocity contd. (ii) *angular*	radians per second revolutions per minute	rad/s rev/min	
flow (volumetric)	cubic metre per second	m^3/s	commonly called the cumec
	litre per second	l/s	
pressure	newton per square metre	N/m^2	the newton is not yet wellknown as the unit of force and kgf/cm^2 will clearly be used for some time. In this field the hydraulic head expressed in metres is an acceptable alternative way of expressing approximate pressure. This is easily visualised. For water under standard conditions: *Equivalent head of pressures* 1 N/m^2 = 0·102 mm 1 kN/m^2 = 0·102 m 1 kgf/cm^2 = 10·0 m The bar (10^5 N/m^2) may be internationally adopted as a unit of pressure.
	kilonewton per square metre	kN/m^2	
	kilogramme (force) per square centimetre	kgf/cm^2	
temperature	degree Kelvin	°K	*Basic SI unit*
	degree Celsius	°C	the Kelvin and Celsius degrees are identical. The use of the Celsius scale is recommended as it is the former centigrade scale. The expression "°C" should be used for a particular temperature (e.g. 60°C), and the expression "degC" for a temperature interval or difference (e.g. raise temperature by 60 degC).
work, energy quantity of heat	joule	J	1 joule = 1 Nm
	kilojoule	kJ	
power	watt	W	1 watt = 1 J/s
	kilowatt	kW	

Application of Units

Description	Unit	Symbol	Comments
precipitation run-off, evaporation	millimetre	mm	for meteorological purposes it may be convenient to measure precipitation in terms of mass/unit area (kg/m^2). 1 mm of rain = 1 kg/m^2
river flow	cubic metre per second	m^3/s	commonly called the cumec
flow in pipes, conduits channels, over weirs, pumping etc.	cubic metre per second	m^3/s	
	litre per second	l/s	
discharges or abstractions yields etc.	cubic metre per day	m^3/d	1 l/s = 86·4 m^3/d
	cubic metre per year	m^3/a	
usage of water	litre per person per day	l/person day	in this case the abbreviation of "day" is not recommended
density	kilogramme per cubic metre	kg/m^3	the density of water under standard conditions is 1 000 kg/m^3 or 1 000 g/l
	gramme per litre	g/l	
concentration	gramme per cubic metre	g/m^3	
	milligramme per litre	mg/l	
calorific value of gas	joule per litre	J/l	temperature and pressure of the gas to be stated.
BOD loading	kilogramme per cubic metre per day	kg/m^3d	
hydraulic load per unit area e.g. filtration rates	cubic metre per square metre per day	m^3/m^2 d	if this is converted to a velocity this should be expressed in mm/s (1 mm/s = 86·4 m^3/m^2 day)

APPLICATION OF UNITS (Cont.)

Description	Unit	Symbol	Comments
hydraulic load per unit volume e.g. biological filters, lagoons etc.	cubic metre per cubic metre day	$m^3/m^3\ d$	
air supply	cubic metre or litre of free air per second	m^3/s l/s	
pipes			
diameter	millimetre	mm	
length	metre	m	

Note: Other derived units may be formed preferably by combining only SI units or other coherently derived units. In case of difficulty reference should be made to B.S.I.

APPENDIX 1

Basic Conversion Factors

(expressed to 4 significant figures)

Metric Equivalent		U.K.	Metric Unit	U.K. Unit Equivalent	
0·3048	m	1 ft	1 m	3·281	ft
1·609	km	1 mile	1 km	0·6214	mile
0·092 90	m^2	1 ft^2	1 m^2	10·76	ft^2
0·4047	ha	1 acre	1 ha	2·471	acres
0·028 32	m^3	1 ft^3	1 m^3	35·31	ft^3
4·546	l	1 gallon	1 l	0·2200	gallon
0·4536	kg	1 lb	1 kg	2·205	lb
4·448	N	1 lbf	1 N	0·2248	lbf
0·070 31	kgf/cm^2	1 lbf/in^2	1 kgf/cm^2	14·22	lbf/in^2
6·895	kN/m^2	1 lbf/in^2	1 kN/m^2	0·1450	lbf/in^2
0·7457	kW	1 hp	1 kW	1·341	hp
1·055	kJ	1 Btu	1 kJ	0·9478	Btu
0·052 61	m^3/s	1 million gallons/day	1 m^3/s	19·01	million gallons/day
0·028 32	m^3/s	1 cusec	1 m^3/s	35·31	cusec
0·075 77	l/s	1 gallon/ minute	1 l/s	13·20	gallons/ minute
0·084 67	mm/s	1 ft/hr	1 mm/s	11·81	ft/hour
0·005 946	m^3/m^3	1 gallon/yd^3	1 m^3/m^3	168·2	gallons/yd^3
0·5933	kg/m^3	1 lb/yd^3	1 kg/m^3	1·686	lb/yd^3

APPENDIX 2

Multiples and Sub-multiples of Units

The names of the multiples and the sub-multiples of the units are formed by means of the following prefixes:

Factor by which the unit is multiplied		*Prefix*	*Symbol*
1 000 000 000 000	$= 10^{12}$	tera	T
1 000 000 000	$= 10^{9}$	giga	G
1 000 000	$= 10^{6}$	mega	M
1 000	$= 10^{3}$	kilo	k
0·001	$= 10^{-3}$	milli	m
0·000 001	$= 10^{-6}$	micro	μ
0·000 000 001	$= 10^{-9}$	nano	n
0·000 000 000 001	$= 10^{-12}$	pico	p

Only one prefix should be used. This applies to the gramme although the kilogramme is the basic SI unit; thus 1 000 kg is called one megagramme.

To avoid confusion with the continental use of the comma as a decimal sign and in view of the possibility of the adoption by the U.K. of the same practice, groups of three digits have been separated by spaces and not by commas, as shown above.